Precise Robust Inertial Guidance for Munitions: Navigation-Grade Inertial Measurement Unit (PRIGM:NGIMU) Proposers' Day

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Proposers' Day Agenda

- PRIGM:NGIMU Introduction and BAA Overview
  - Program objectives
  - BAA and proposal process
  - Government T & E capabilities
- Open Q & A Session
  - Write your questions on the notecards provided
  - Submit questions before the Q & A session begins
- Attendee Presentations
  - 12 minutes to speak, 3 minutes for questions
  - Please help maintain the schedule

Munitions Navigation

GBU-31 JDAM

Nav

GBU-53 SDB-II

AGM-114 Hellfire

Navigation System

~~GPS~~

INS

Algorithms

Inertial Navigation System (INS)

Clock

IMU

∫∫∫

Inertial Measurement Unit (IMU)

Gyro

Gyro

Gyro

Accel

Accel

Accel

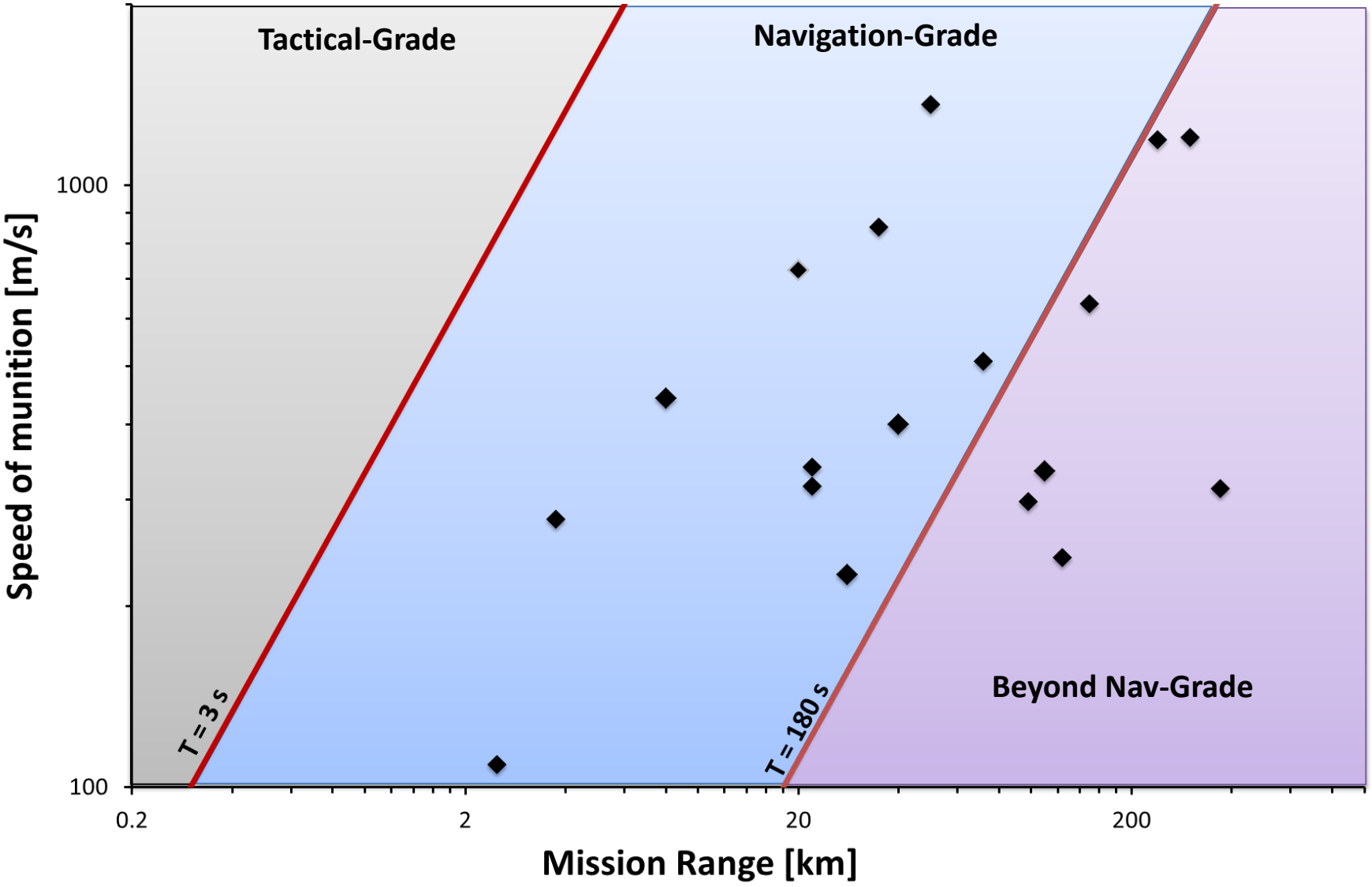
Sensor Control & Readout

Output:
x, y, z, v_x, v_y, v_z

Output:
x, y, z, v_x, v_y, v_z

Output:
$a_x, a_y, a_z, \dot{\alpha}, \dot{\beta}, \dot{\gamma}$

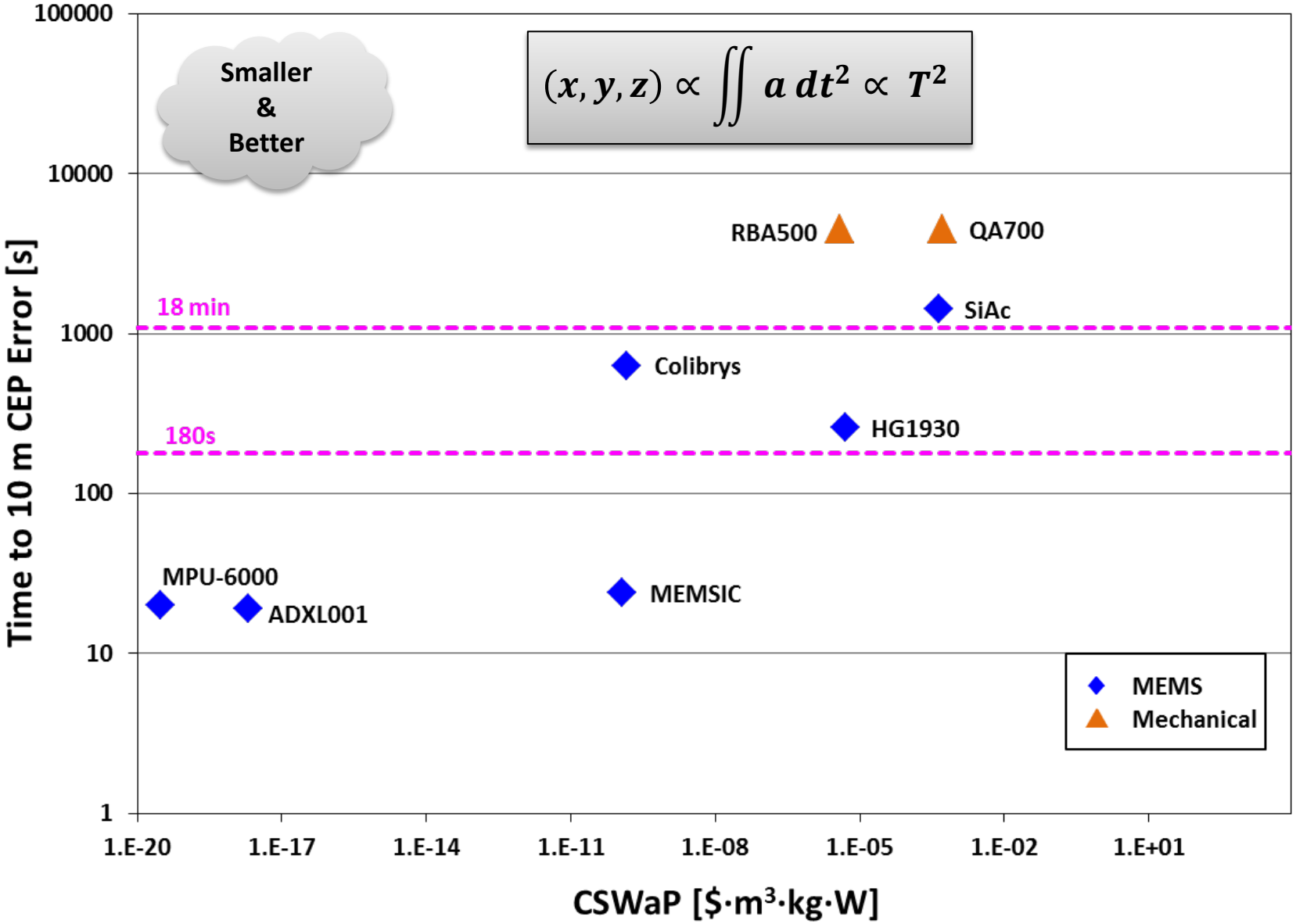
Simplified Missile/Munition Profiles



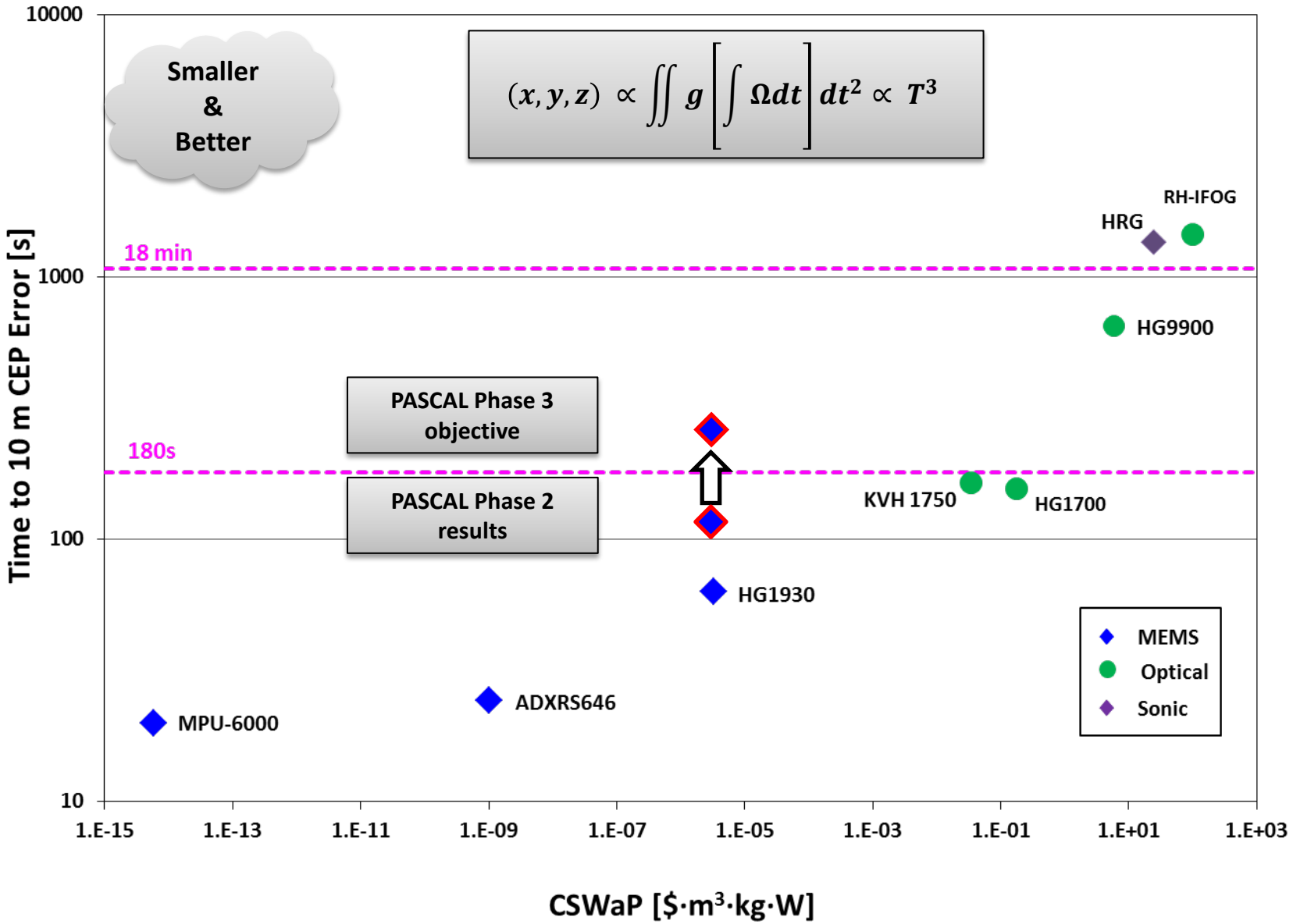
Munitions Navigation

	Current State	Capabilities Enabled by Navigation-Grade MEMS
Air-to-Ground Munition	• Requires GPS tracking until impact • IMU used for stabilization • Inertial-only nav to 30 s (5 km) **Challenge: Transfer alignment**	• Reduced CSWaP INS • Inertial-only nav to 180 s (60 km) • Reduce transfer alignment time
Ground-to-Ground Munition	• Requires GPS tracking until impact • IMU used for stabilization • GPS required for terminal arming **Challenge: Must survive gun launch**	• Inertial-only nav to 180 s (250 km) • Transfer alignment from GPS in first 10-15 s of glide flight • Must survive gun launch
Missile	• IMU used for stabilization • Laser seeker for terminal guidance **Challenges: Long-range navigation, transfer alignment**	• Extend terminal jamming radius to 180 s (250 km stand-off range) • Beyond line-of-sight navigation • Reduce transfer alignment time

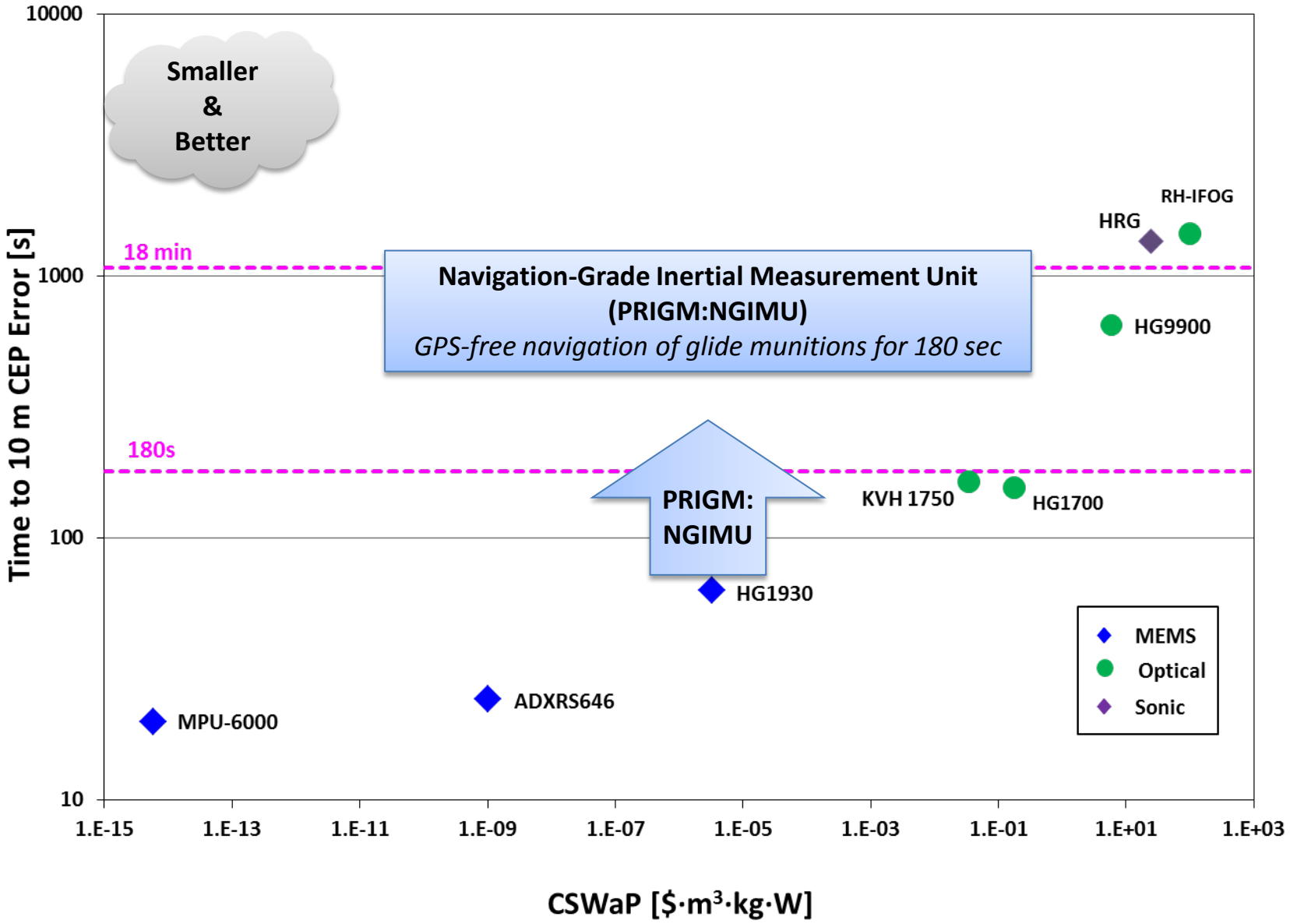
SOA Accelerometers



SOA Gyroscopes



SOA Gyros: Path Forward to Advanced MEMS IMUs



Nav-Grade Inertial Measurement Unit (PRIGM:NGIMU)

Motivation

- Enable guided munitions in GPS-contested theaters by 2020

Objective

- Eliminate compromise between **low-CSWaP, tactical-grade MEMS** and **high-CSWaP, navigation-grade RLG/iFOG-based IMUs**
- Develop prototype drop-in replacement **navigation-grade MEMS IMUs** in 2019
- Flight demos in 2020

Navigation-grade performance with MEMS CSWaP

Nav-Grade IMU
Ring laser gyros, quartz accels

vs.

Tactical-Grade IMU
MEMS gyros & accels

PRIGM:NGIMU

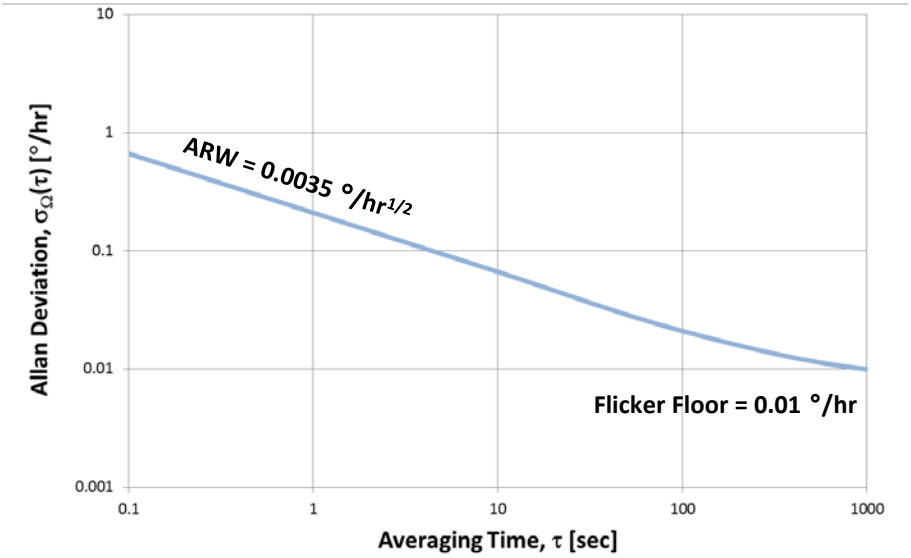
Navigation-Grade IMU
SOA MEMS gyros & accels

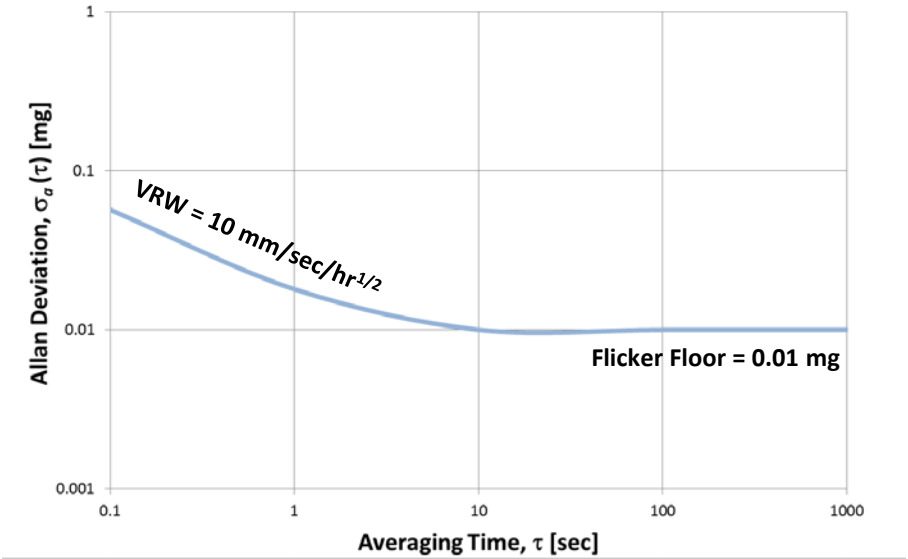
PRIGM:NGIMU Program Objectives

Program Deliverables: 10 MEMS-based IMUs with navigation-grade performance that are drop-in replacements for DoD-standard tactical-grade IMUs

Performance Metric	Objective	Units
Volume	82	**cm^3**
Weight	160	**g**
Power	< 3	**W**
Operating temperature range	-54 to +85	**°C**
Vibration DC to 2 kHz	7.7	**g_{RMS}**
Shock survivability	20,000	**g**
Bandwidth (min. @ -90° phase lag)	70	**Hz**
Gyroscope		
Operating range	± 900	**°/sec**
Turn-on to turn-on bias repeatability	0.01	**°/hr, 1σ**
Scale factor repeatability	5	**ppm**
Accelerometer		
Operating range	± 60	**g**
Turn-on to turn-on bias repeatability	25	**µg, 1σ**
Scale factor repeatability	25	**ppm**

PRIGM:NGIMU Program Objectives





Stability Specification (Allan Deviation)		
τ [sec]	Gyroscope $\sigma_\Omega(\tau)$ [°/hr]	Accelerometer $\sigma_a(\tau)$ [mg]
0.1	0.66	0.19
1	0.21	0.06
10	0.066	0.01
100	0.021	0.01
1000	0.01	0.01

Proposal Information

A. Innovative Claims
B. Technology Basis
C. Detailed Technical Approach
D. Test plan
E. Risk analysis
F. Schedule, milestones, and budget
G. Technology Transfer
H. Comparison with related research
I. Biographies of key personnel
J. Facilities
K. Statement of Work (SOW)
L. Summary Slide

Evaluation Criteria

- Overall scientific and technical merit
- Realism of proposed schedule
- Plans and capability to accomplish technology transition
- Cost realism
- Proposers' capabilities and/or related experience
- Potential contribution and relevance to the DARPA mission

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